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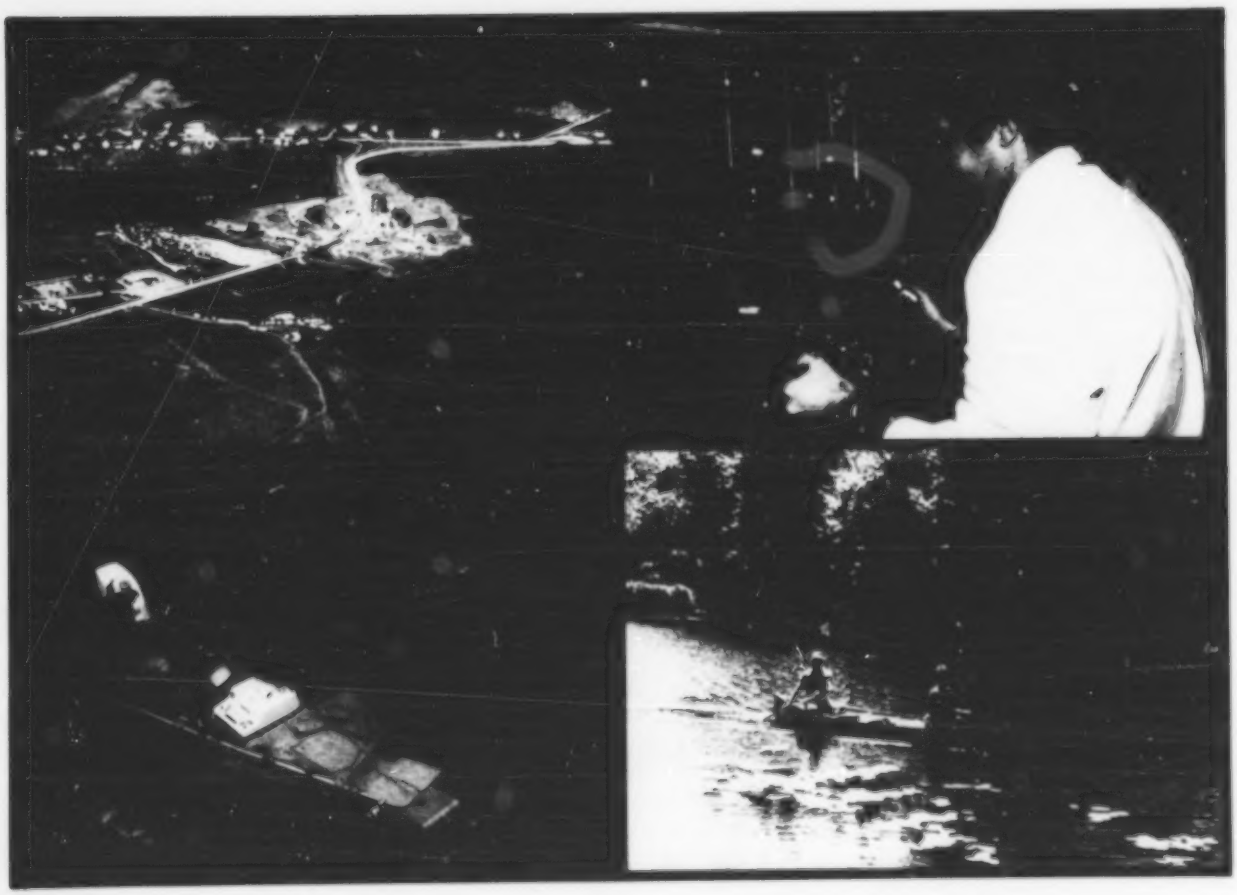
Chemical Grouping of Environment Canada's Lake Acidification Monitoring Sites in Atlantic Canada

IWD-AR-WQB-91-168



Canada

INLAND WATERS DIRECTORATE
ATLANTIC REGION
WATER QUALITY BRANCH
MONCTON, NEW BRUNSWICK

Chemical Grouping of Environment Canada's Lake Acidification Monitoring Sites in Atlantic Canada

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Tech. Rep. IWD-AR-WQB-91-168

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July 1991

ABSTRACT

The Water Quality Branch of Environment Canada has been operating a lake monitoring network in a large area of Atlantic Canada. The network was originally conceived to follow both temporal and spatial trends in water acidification parameters. In order to facilitate the understanding of spatial acidification trends, it was found necessary to expand the network into eastern Nova Scotia. However, to minimize the number of lakes to be sampled, it was also found necessary to select new lakes based on chemical characteristics which would allow comparisons between similar lakes from one end of the region to the other.

Based on organic anion and base cation chemistry which control water pH, all existing and potential new lake sites were grouped using a clustering analysis, based on . The results showed that most lakes in the region could be placed in five groups: low A^-, low C_b^*; low A^-, moderate C_b^*; high A^-, high C_b^*; moderate A^-, moderate C_b^* and moderate A^-, high C_b^*. Only sites with low A^-, low C_b^* and low A^-, moderate C_b^* were commonly found in both Nova Scotia and Newfoundland. Based on the clustering results, new monitoring sites which were suitable for determining acidification effects were thus identified from a a large group of potential lakes.

MANAGEMENT PERSPECTIVE

Data collected since 1983 in the WQB lake acid precipitation monitoring network in the Atlantic Provinces, showed that a number of sites were unsuitable for acidification trend analysis because of contamination from anthropomorphic activity or because of unsuitable geology. The network also showed gaps in coverage due to large areas of Nova Scotia not being sampled, making spatial differentiation of acidification trends impossible. Because of this, it was deemed necessary to add a number of new lakes to the network from eastern Nova Scotia.

In order to identify new Nova Scotia sites suitable for sampling, to exclude those with unacceptable chemical characteristics and to incorporate all monitoring sites in Atlantic Canada into a common base for comparison, both original and potential new lakes were grouped into statistically derived clusters based on water chemistry characteristics specifically chosen to reflect geochemical acidification controls. The clustering exercise thus reevaluated existing sampling sites and identified potential new locations to produce a better coverage and aid in the interpretation of sampling results.

PERSPECTIVES POUR LE GESTIONNAIRE

Les données prélevées depuis 1983 dans les lacs du réseau de surveillance d'acidification des Provinces Atlantiques ont démontré qu'un nombre de sites étaient mals adaptés pour l'analyse de tendances temporelles ioniques dû à des problèmes de contamination dans leurs bassins versants, ou dû à une géologie mal adaptée. Il y avait aussi une partie de la Nouvelle Ecosse qui n'était pas échantillonnée, laissant un vide géographique qui rendait une distinction spatiale des tendances d'acidification impossible à faire. Il fut donc nécessaire d'ajouter un nombre de nouveaux lacs dans les régions de l'est de la Nouvelle Ecosse, ainsi que d'éliminer les lacs qui ne représentaient pas des situations typiques.

Pour identifier de nouveaux lacs convenables, exclure ceux avec des caractéristiques chimiques inacceptables, ainsi qu'incorporer tous les sites de la région dans une base commune, tous les lacs ayant des données furent groupés selon leurs charactéristiques chimiques. Deux variables, la concentration d'acides organiques estimée selon la méthode Oliver et al. (1983) ainsi que la somme des cations de base (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}), furent utilisées comme base pour fins de comparaison. Les lacs convenables furent alors divisés en cinq groupes basés sur leurs caractéristiques chimiques, nous aidant alors à produire une meilleure interprétation des résultats du programme d'échantillonnage.

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INTRODUCTION

The Water Quality Branch (WQB), Inland Waters Directorate, of Environment Canada is the lead agency responsible for monitoring surface water acidification trends in Atlantic Canada. Since 1982, the Branch has sampled a number of lakes during both spring and fall water mixing periods in the provinces of Nova Scotia and Newfoundland in order to collect data suitable for the detection of trends in acidification parameters.

One goal of lake acidification monitoring networks is to assess spatial differences in chemistry over large areas. Though informative, successful data interpretation from those networks can require large data sets, as water quality variables are dependent on combinations of factors such as geological, climatic, and land-use effects. One way of approaching the assessment is to compare lakes with similar geochemical characteristics to eliminate some of the factors which produce the natural background "noise".

Atlantic Canada is composed of four provinces located in northeastern North America. Its geology ranges from limestone outcrops, to slates and sandstones, to granites (Ehrman et al. ms). Of the four political entities (New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland and Labrador), only Nova Scotia and Newfoundland have significantly large areas susceptible to aquatic acidification (Clair et al 1982). Labrador, which is part of Newfoundland, is also susceptible, but its location in the far northeastern end of the continent protects it against high loadings of acidifying precipitation (Clair 1991). From western Nova Scotia to eastern Newfoundland, a gradient of acid precipitation effects has been documented in freshwater chemistry (Thompson 1982, Jeffries et al 1986). The data used to measure that gradient however, were geographically scattered, variables were analyzed using different analytical techniques, and

samples were collected at different times of the year, making it impossible to measure changes in spatial trends in the region from year to year.

The lakes sampled by WQB since 1982 (initial lakes) were selected from the scattered database then available. Those historical water chemistry data (from 89 sites in Nova Scotia and 152 in Newfoundland) were used to separate lakes into groups with similar water chemistries (Esterby et al. 1989). Lakes representative of each group, or from particular regions were then chosen to be part of the network, in view of logistical constraints, as well as geological sensitivity to acidification. One shortcoming of the data used in the original analysis, was that no background information existed from central and eastern Nova Scotia, so that no sites were selected from those areas. In addition, a number of new lakes were added in Newfoundland due to a network expansion in Gros Morne National Park and collaborative work with Fisheries and Oceans Canada. These new sites were not placed in clusters where they could be objectively compared to other lakes.

With time, understanding the factors which determine surface water acidity improved, as did the quality and quantity of the water chemistry data available. The suitability of the lakes included in the initial set also had to be reconsidered. The most apparent inadequacy, in view of the east-west acid deposition gradient, was the absence of lakes from the central and eastern parts of Nova Scotia. Moreover, the initial clustering of Nova Scotia and Newfoundland sites was not done with similar data from each region. The initial clustering was done using SO_4^{-2}, Ca^{+2} (both seasalt corrected), Cl^-, water colour (plus total organic carbon in Newfoundland), pH, acid neutralization capacity (ANC), and specific conductance, all in standardized units. This gave approximately equal importance to each variable in the analysis. However, those parameters

included not only basin characteristics involved in acid precipitation interpretation, but also Cl^- an indicator of marine influence. The Newfoundland SO_4^{-2} values used were acquired using the methyl thymol blue technique known to overestimate concentrations in coloured waters (Howell and Pollock 1986).

Because the set of water chemistry variables for the two provinces differed, cluster analysis was performed separately for each region. A result of this was that the cluster groups in each province were dominated by different parameter centroid values making comparison of lakes between the two regions impossible. Since the objective of the network is to compare lakes which would be expected to respond similarly to acidifying precipitation, it was decided to reevaluate the parameters upon which suitable groupings could be made. A reappraisal of the original lake groupings into a regional framework, and not simply within each province was to provide a regional picture.

A number of water quality interpretation questions first had to be addressed. Buffering of water acidity by basin bedrock is important in explaining aquatic acidification. Lakes situated on calcareous and other soft bedrock generally have higher bicarbonate and base cation (C_b) concentrations, indicating greater natural acid neutralization capacity, than those located on silicate bedrocks (Kramer 1976, Kilham 1982, Schnoor and Stumm 1986).

In Atlantic Canada waters, natural organic acids, which are estimated by surrogates such as colour or dissolved organic carbon (DOC), or calculated as organic anion concentration (A^-) (Oliver et al. 1983) are also important in controlling pH. Those acids are generated by the breakdown of natural terrestrial and aquatic organic detritus and decrease water pH levels. Because of this, the water acidity component due to anthropogenic effects cannot be easily

differentiated in some lakes and rivers. The organic acidity effect is also superimposed on the bedrock buffering situation described above.

The third complication which has to be dealt with in interpreting Atlantic Provinces freshwater chemistry, is the influence of marine spray. In Nova Scotia and Newfoundland, seaspray can contribute 25% or more of the sulfate (SO_4^{-2}) and base cations in precipitation (Vet et al. 1986) and thus in surface waters. That fraction is accounted for by assuming that all chloride (Cl^-) in rain or lake water is of marine origin, is biologically and geologically conservative, and that seawater Cl^- ion ratios are conservative (Watt et al. 1979). The seasalt corrected base cation portion is identified as C_b^*. It was thus decided to use C_b^* and A^- for the clustering process, as they are the two parameters which were most important in determining water acidity and buffering.

Based on potential buffering from bedrock, it was assumed that the best sites for inclusion in a network for monitoring acidification trends were those with low C_b^* and low A^-, followed in order of preference by those with low C_b^* and moderate A^-, moderate C_b^* and low A^- and moderate C_b^* and moderate A^-, moderate C_b^* high A^-, and high C_b^* moderate A^-. Those most likely to provide data which would not contribute to the study of anthropogenic acidification are those with both high C_b^* and A^-.

The main dependant variable on which to base the extent of acidification effects is seasalt corrected SO_4^{-2} (SO_4^{-2*}). This parameter is more reliable than pH, as it is less likely to be influenced by geological and biological factors. Acidity measured as pH, is also important, but because of potential interference effects, it is less likely to provide useful information on acidification trends. Another variable often used as an indicator of acidification status is the acid

neutralization capacity (ANC) of water. It indicates the potential of the sample to take up hydrogen ions, and used comparatively will allow an analysis of the potential of a sample to have its pH modified. High ANC suggest that little change in pH will occur with increases in acid deposition.

In order to provide data suitable for spatial as well as temporal trend analysis, the existing network was modified by a) reclassifying existing stations into groups more amenable to interpretation, and b) adding suitable sites in critical areas where information gaps existed. The purpose of this paper is then to describe results of the clustering of both existing and potential new sites into relatively geochemically homogeneous groups by using only C_b^* and A^- in the clustering process. The new lakes considered for addition to the network were examined to determine if they fell within cluster groups suitable for acidification trend monitoring. The clusters generated were compared to those produced in the original clustering exercise conducted by Esterby et al. (1989) to see how changes in the basic clustering parameters changed the groupings of stations within zones already being sampled.

STUDY AREA AND METHODS

The two provinces monitored are shown in Figures 1 and 2. Initial sites regularly monitored are located in Zones A,B in Nova Scotia and F,G,H,J in Newfoundland. New data from 131 sites in Nova Scotia Zones C,D and E were also chosen for inclusion into the clustering program. These sites, sampled under a number of federal and provincial programs in the Atlantic Region since 1981 (LWG 1989) were located approximately 100 km east and west of Halifax, as well as 70 km north of Sydney in Nova Scotia (Fig. 1).

Zone C,D and E lake basins were studied to see if they fitted a number of basic criteria, the most important being that they were in areas not likely to be disturbed by major human influences, and that they were headwater lakes. Ground proofing and topographic and land use maps were used to ensure that large-scale development did not impact on lakes, either from within the basin, such as housing and mining, or from outside such as local transport of atmospheric pollutants (Shaw 1986).

The only clustering variables used in this exercise were the sum of seasalt corrected base cations (C_b^*), calculated by adding the seasalt corrected equivalents of Ca^{+2}, Mg^{+2}, K^+, Na^+ and the organic anion component of the water (A^-) calculated using the Oliver et al. (1983) method. The data used from the original sites were the median values measuredat each site since 1983. The data for 131 of the potential new sites were taken from the LWG (1989) data set.

All data from the existing network and potential new sites were grouped using the clustering approach described by Esterby et al. (1989) and El-Shaarawi et al. (1989). The analysis was done on standardized variables with a non-hierarchical nearest centroid procedure

Figure 1 Sampling Zones in Nova Scotia.

using four to six clusters. Initial seed-points were determined as points equally spaced within the range of values for each variable. For a specified number of clusters, on the first pass, the procedure assigns each lake to the cluster to which it is nearest in terms of the Euclidean distance between the variable values for that lake and the vector of cluster centroids. The cluster centroids are then recalculated as the mean of each variable for all lakes in the cluster. The process of reassignment and updating of centroids is continued until there is no change in cluster membership on two successive iterations.

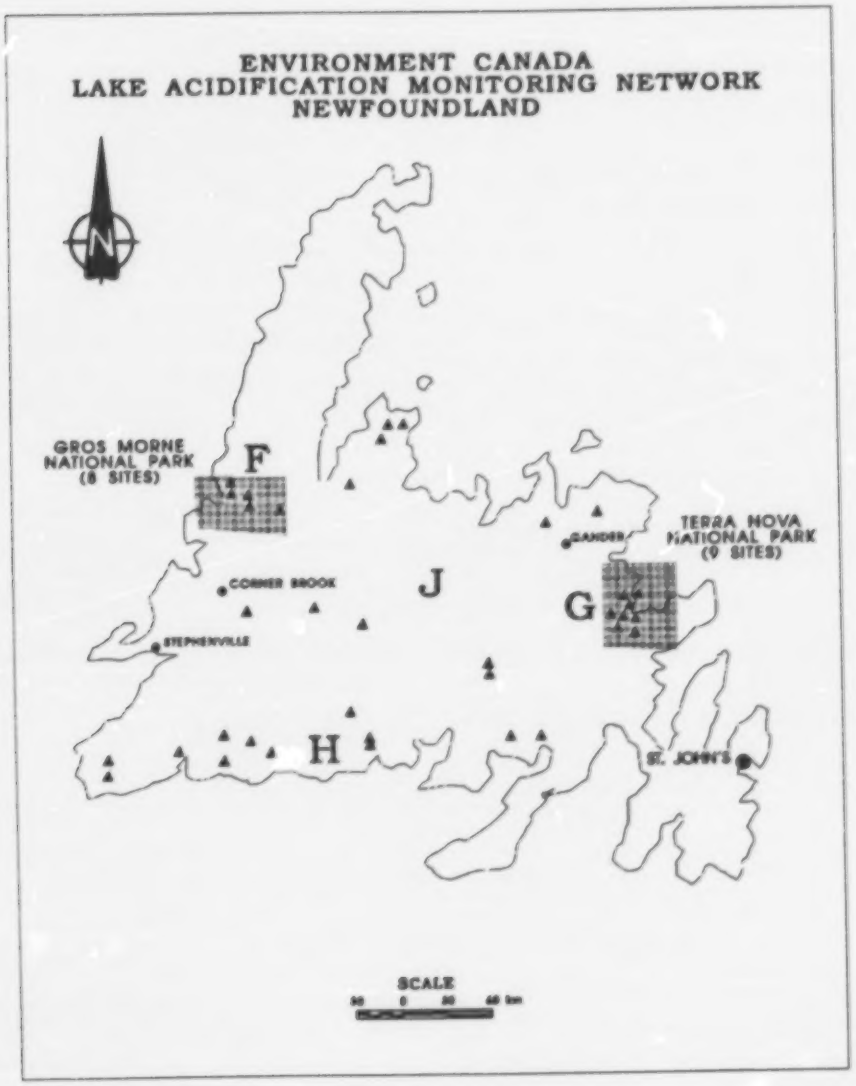

Figure 2. Sampling Zones in Newfoundland.

For each number of clusters, the proportion of the total variation for all variables accounted for by the clusters was calculated as a ratio of sums of squares.

RESULTS AND DISCUSSION

Overall lake chemistry of Atlantic Canada lakes was summarized from the LWG (1989) Nova Scotia and Newfoundland data sets to give an idea of the range of base cation and organic anion concentrations found in the region (Table 1).

Table 1. Summary statistics for the total sample lake population in Atlantic Canada. Concentrations are in $\mu eq*L^{-1}$.

	A^-	C_b^*
Total	256	256
mean	49.2	104.5
median	42.1	84.9
maximum	180.9	748
minimum	9.7	20
skewness	1.4	3.5
kurtosis	2.8	20.3

The results show generally dilute waters with low C_b^* and high A^- values, compared to those from waters from other areas in Europe and North America (Jeffries et al. 1986, Linthurst et al. 1986, Kortelainen et al. 1989). Based on the ranges calculated, and in order to further simplify discussion, variables were arbitrarily described as low A^- if less than 35 $\mu eq*L^{-1}$, high A^- if the values were greater than 60 $\mu eq*L^{-1}$ and moderate in between. The C_b^* values less than or equal to 65 $\mu eq*L^{-1}$ were described as low, greater than or equal to 105 as high, and in between as mid-range.

It can be seen that the A^- data are less skewed than the C_b^* data. The base cation mean

is highly influenced by a small number of very high values. Based on the regional analysis, all sites with C_b^* values greater than 250 $\mu eq*L^{-1}$ were removed from the clustering data base, as they did not represent typical situations, were unlikely to reflect any changes in water acidity due to acid deposition, and severely complicated the clustering analysis. Moreover, sites with high C_b^* from limestone or gypsum are more likely to contain bedrock SO_4^{-2} than granites or feldspars, and are thus more likely to generate "contamination" effects which would confuse acidification trend estimation.

Results of the clustering analysis (Table 2) showed that six clusters provided the maximum cluster means square for the combined new and original Atlantic region lake set. However, as Cluster 6 only contained one site high in both A^- and C_b^*, that site was removed from further analysis. The data show that 27% of lakes in the selected data base fell into the low C_b^* and A^- group (Cluster 1), with Cluster 2 and 3 sites constituting a further 47%. No sites showed low C_b^*, moderate A^- characteristics.

Table 2. Centroid values for total monitoring lakes. Parameter values are in $\mu eq*L^{-1}$. The first column indicates the number of clusters used, the last, the analysis of variance over all variables. The percent value indicates the proportion of lakes in each cluster, and R, the percent variation accounted for by the clusters.

	Cluster												
	#1		#2		#3		#4		#5		#6		R
#	C_b^*	A^-	C_b^*	A^-	C_b^*	A^-	C_b^*	A^-	C_b^*	A^-	C_b^*	A^-	
4	61.6	29.1	74.1	60	179	47.1	104	113	-	-	-	-	70
%	44		29		19		8		-		-		
5	55.1	26.9	76.7	48.1	179	47.1	67.6	83.1	134	109	-	-	76
%	35		27		19		16		2				
6	40.0	28.2	95.6	32.2	74.1	60.0	179	47.1	82	94	218	116	79
%	27		23		24		18		7		1		

An analysis of the regional distribution of Clusters (Table 3) suggests that only lakes in Clusters 1 and 3 can be used for comparison of regional spatial trends, as the distribution of other Cluster groups is patchy. For example, only two Cluster 2 sites were found in all of Newfoundland, and Cluster 4 sites were found in Nova Scotia only in Zone A. Cluster 5 sites are not only poor indicators of acidification effects, but are also few in number. Most groups were represented in regions A and B of Nova Scotia. Newfoundland (Table 3).

In order to improve the network's spatial coverage, 31 new lakes from Clusters 1, 2 or 3 (of the initial 131 looked at) were added in areas C, D, and E, of Nova Scotia (Appendix A).

Table 3 Regional cluster distribution of lakes. In Nova Scotia, Zone A is the Yarmouth region; B is the Kejimkujik National Park; C is the New Germany region; D, the Eastern Shore; E Cape Breton Highlands National Park. In Newfoundland, Zone F is the Gros Morne National Park; G, Terra Nova National Park; H is the south coast; J is the central and northern area.

Province (Zone)	Clust. 1	Clust. 2	Clust. 3	Clust. 4	Clust. 5
Nova Scotia	28	15	20	7	4
ZONE A	2	5	1	7	1
ZONE B	10	1	13	0	3
ZONE C	1	6	0	0	0
ZONE D	4	0	3	0	0
ZONE E	11	3	3	0	0
Newfoundland	16	2	10	8	3
ZONE F	6	0	0	1	0
ZONE G	0	0	5	2	2
ZONE H	9	1	2	0	0
ZONE J	1	1	3	5	1

The lake cluster distribution, based on variables used is shown in Figure 3. The centroid values for each cluster are noted by letters. The graph shows a greater range of C_6^* values than A^*. It also tends to show that Cluster 1, 2 and 3 sites have tighter variable distributions than Clusters 4 and 5. Again, centroids from the first three groups, are more descriptive of their cluster chemistry than the other two. Figure 3 can thus be used to roughly classify any Atlantic Region lake whose geochemical characteristics are being analyzed.

The comparisons that can be made with the original work done by Esterby et al. (1989) are limited because of the differences between sets of data, both in lakes included and variables used. Of the 62 Nova Scotia lakes used in the original clustering of seven variables, only 42

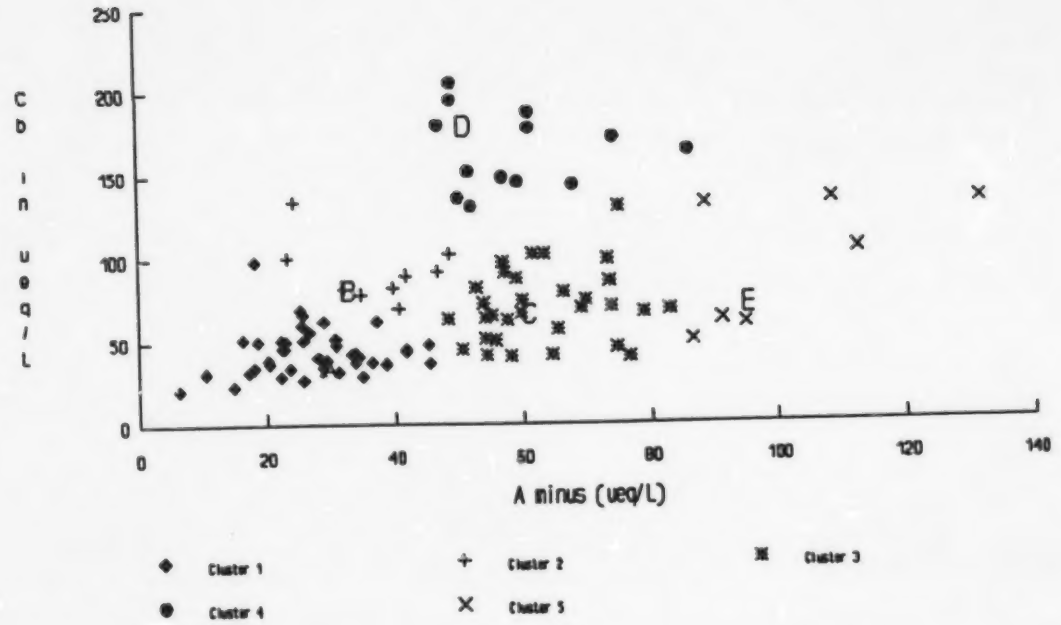

Figure 3 Cluster group distribution relative to clustering variables.

were included in the current set of 74 sites. Similarly, of the original 152 Newfoundland lakes clustered on the basis of eight variables, only 24 were included in the current set of 40.

Since the clustering algorithm groups lakes with the most similar variable values in the set being clustered, very different cluster memberships with respect to the lakes common to both analyses are possible. The effect of the different variable sets may not be great however, since the two calculated variables (A^- and C_b^*) were obtained either from variables used in the original clustering, or from variables which are highly correlated with them.

Despite the data set differences, some similarities exist in the results. In the original analysis (Esterby et al. 1989), the lakes were divided into two large clusters in Nova Scotia

(Clusters 1 and 2), and three in Newfoundland (Clusters 1,2,7). For NS lakes, Clusters 1 and 2 were distinguished from each other primarily by the higher water colour values in Cluster 2. Similarly, in Nfld lakes, Cluster 2 was distinguished from 1 and 7 by higher colour and DOC, though Cluster 7 sites also had higher pH, specific conductance and Ca^{+2} than the others.

Comparison of Ca^{+2} and colour (taking these variables as indicative of C_b^* and A^- values) for clusters in both provinces, shows that Cluster 2 in both places has similar colour, but the Nfld Cluster 2 contains a high proportion of lakes with higher Ca^{+2} than the NS Cluster 2. Further, Cluster 1 lakes in both provinces is similar in colour, again with some Nfld lakes showing higher Ca^{+2}. From this, it is expected that lakes assigned to Cluster 1 in both provinces in the original analysis, would appear in the same clusters in the new analysis.

Table 4 shows that this indeed occurred. The lakes in the original Cluster 1 were assigned primarily to the new Clusters 1 and 3, where both C_b^* and A^- increase for Cluster 3 over Cluster 1. Those in the original Cluster 2 go to new Clusters 3 and 5, with the difference being higher A^- in Cluster 5. Since Cluster 1 and 2 lakes in the original analysis were Zone B sites (Kejimkujik), the lakes here are now differentiated into 3 groups instead of two, allowing a better understanding of chemistry differences.

In the present analysis, some of the Yarmouth lakes (Zone A) are now in the same clusters (1,2,3,5) as the Kejimkujik sites, whereas they were originally assigned to small clusters 3 and 7. A common feature of the two analyses is the distribution of Zone A lakes amongst several (though different) clusters, demonstrating the strong role played by the confused local geology (Ehrman et al., ms).

Table 4. Comparison of cluster membership for lakes included in original and present analyses.

a) Nova Scotia

New Cluster #	Number of Lakes Original Cluster Number							
	1	2	3	4	5	6	7	Total
1	10	-	2	-	-	-	-	12
2	1	-	3	2	-	-	-	6
3	5	9	-	-	-	-	-	14
4	-	-	1	-	3	1	1	6
5	-	4	-	-	-	-	-	4
6	-	-	-	-	-	-	-	0
Total	16	13	6	2	3	1	1	42

b) Newfoundland

New Cluster #	Number of Lakes Original Cluster Number							
	1	2	3	4	5	6	7	Total
1	6	-	-	-	-	-	-	6
2	2	-	-	-	-	-	-	2
3	3	4	-	-	-	-	1	8
4	-	2	-	-	-	-	4	6
5	-	2	-	-	1	-	-	3
6	-	-	-	-	-	-	-	0
Total	11	8	0	0	1	0	5	25

In general, this type of comparison could not be done for the Newfoundland lakes, as the sites assigned to any one cluster were too geographically dispersed to compare the results of the analyses by region. Overall, the main differences in results between the two clustering exercises in Zones A,B,G,H and J seemed to be that the new analysis improved the separation of lakes into a larger number of more homogeneous groups in Kejimkujik National Park. The reduction in the total variability which results from using the calculated variables produces fewer clusters, although the different sets of lakes prevent direct comparisons.

Lakes with similar geological and soil influences, as determined by base cation and organic anion characteristics, can now be matched from western Nova Scotia to eastern Newfoundland providing a reliable regional base for comparison. Data generated from sampling trips can then be used to provide year by year variations in SO_4^{-2} distribution in Atlantic Canada. Where long enough data sets exist (ie in the original lake set), the data can also be used to assess long-term trends in acidification from western Nova Scotia to eastern Newfoundland, thus providing a comprehensive assessment of the success of international and national SO_4^{-2} control strategies.

CONCLUSIONS

In order to simplify the interpretation of spatial and temporal trend data, both existing and potential new sampling sites to Environment Canada's Atlantic Region lake acidification monitoring were included in a clustering analysis to group together lakes with similar chemical characteristics. The results of the procedure now permit logical regional comparisons of lake water constituents, especially pH and SO_4^{-2}.

The inclusion of a number of suitable new sites identified by the clustering analysis, also permits trend analysis along a southwest to northeast gradient which was not possible before, because initial groupings in the two main regions studied, Nova Scotia and Newfoundland, were not based on identical parameters, and because of large gaps in coverage. Moreover, the use of the calculated variables A^- and C_b^*, together with categorization of low, medium and high parameter levels, has made it easier to identify sensitive lakes, as well as those with characteristics which can confound the interpretation of aquatic acidification effects.

ACKNOWLEDGEMENTS

The authors thank G.D. Howell who managed the Water Quality Branch acidification monitoring network for a number of years and Dr. T.L. Pollock who critically reviewed the manuscript.

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Appendix A

NAQUADAT number, name, Cluster group, Area and location of initial and new Nova Scotia lake sites in the monitoring network. The "C" denotes the lake's Cluster group, and "Z" the zone in which it is found.

Station #	Lake name	C	A	C_b^*	Z	Lat.	Long.
INITIAL SITES						° ' "	° ' "
01NS01DA0002	Tedford	2	23.6	100.2	A	44 06 00	66 01 00
DA0003	Killams	2	32.2	81.0	A	44 00 03	66 04 57
DA0004	Cedar	4	52.1	130.7	A	44 01 36	66 06 39
DA0005	Cornings	2	46.7	91.5	A	44 03 00	66 05 00
DA0006	Pierce	2	41.7	89.2	A	44 07 10	66 05 50
DA0007	Coggins	4	86.3	163.3	A	43 58 42	66 06 30
EA0002	George	1	25.5	68.5	A	44 00 00	66 04 00
EA0004	Jesse	1	28.6	39.3	A	44 01 59	66 00 29
EA0009	Brenton	5	131.7	132.5	A	43 57 41	66 04 09
EA0010	Trefrey	4	51.8	151.7	A	43 50 07	66 02 38
EA0011	Allens	4	47.1	179.4	A	43 56 47	66 09 11
EA0014	Churchill	4	49.2	194.6	A	43 59 26	66 08 21
EA0016	Darlings	4	59.5	145.3	A	43 58 05	66 07 17
EA0019	Snare	3	73.6	85.2	A	44 06 20	65 58 32
EA0020	Bird	2	24.6	133.8	A	43 58 23	65 56 39
ED0001	Back	1	31.0	47.3	B	44 17 30	65 16 00
ED0002	Big Dam W	3	69.8	74.3	B	44 27 30	65 17 30
ED0003	Big Dam E	1	29.1	61.6	B	44 27 00	65 16 00
ED0004	Mountain	1	28.6	39.3	B	44 19 30	65 16 00
ED0005	Peskowesk	1	41.7	43.7	B	44 19 00	65 17 00
ED0006	Grafton	2	40.6	69.5	B	44 23 00	65 10 00
ED0007	Kejimkujik	3	54.1	63.5	B	44 22 00	65 13 30

ED0008	High	3	65.5	56.6	B	44 21 30	65 15 30
ED0010	Pebblelogitc	3	64.5	41.3	B	44 19 00	65 21 00
ED0011	Cobrielle	1	20.6	36.2	B	44 19 00	65 14 00
ED0013	Ben	1	41.3	28.7	B	44 20 30	65 20 00
ED0014	Big Red	5	86.7	49.7	B	44 21 00	65 23 00
ED0015	Mud	3	60.0	74.1	B	44 21 30	65 13 30
ED0016	Snake	5	91.3	62.0	B	44 21 30	65 12 30
ED0017	Liberty	1	33.9	42.3	B	44 23 00	65 25 30
ED0019	F. Ocean	3	69.1	69.5	B	44 27 00	65 21 00
ED0020	Channel	3	73.9	70.2	B	44 25 00	65 18 30
ED0021	Little Red	5	95.0	59.7	B	44 20 21	65 23 45
ED0022	Poplar	1	45.2	47.8	B	44 21 30	65 26 30
ED0025	Luxton	3	50.6	44.6	B	44 21 30	65 20 30
ED0027	Beaverskin	1	17.4	31.3	B	44 18 30	65 20 00
ED0028	McGinty	3	63.5	102.0	B	44 21 30	65 09 30
ED0029	Peskawa	3	54.2	51.1	B	44 19 00	65 22 00
ED0030	Upper Silver	1	25.7	59.3	B	44 17 00	65 15 00
ED0043	Mount Tom	3	58.3	40.9	B	44 22 05	65 18 00
ED0047	George	3	54.7	62.4	B	44 20 25	65 13 15
ED0048	Loon	3	55.3	65.2	B	44 19	65 11
NEW SITES							
01NS01EE0006	L. Tupper	1	18.5	97.8	C	44 25	64 58
EE0010	Annis	2	20.6	94.9	C	44 20	64 50
EE0028	Huey	2	26.3	77.4	C	44 23	64 44
EE0030	Hirtle	2	44.2	97.3	C	44 28	64 45
EE0031	Mathew	2	45.0	115.9	C	44 20	64 41
EF0016	Little Wiles	2	18.5	83.1	C	44 24	64 39
EF0017	Rocky	2	29.4	75.0	C	44 29	64 44
EM0002	Halfway Bk	3	53.9	72.4	D	44 56	62 27

EN0006	Hooper	3	59.8	66.6	D	45 01	62 03
EN0008	Paul Morris	1	36.9	36.5	D	44 57	62 22
EN0009	Nowlan	1	26.9	55.1	D	44 59	62 22
EN0012	Kelly	1	26.0	50.5	D	45 03	62 20
EN0015	Big Pond	3	79.0	66.4	D	44 59	62 25
EN0016	Murphy	1	40.6	101.8	D	44 54	62 22
FD0003	Long Pond	2	39.8	81.8	E	46 42	60 26
FD0004	Warren	2	48.6	102.0	E	46 43	60 21
FD0005	Cradle	2	34.9	78.0	E	46 44	60 26
FD0009	Branch	1	41.8	33.3	E	46 44	60 27
FD0010	Glasgow	3	76.7	40.1	E	46 49	60 30
FD0011	John Dee	3	54.3	41.1	E	46 48	60 31
FD0012	Mica Hill	3	74.7	45.4	E	46 48	60 62
FD0013	Two Island	1	23.2	14.9	E	46 39	60 35
FD0015	Islands	1	38.3	29.5	E	46 44	60 30
FD0018	Gull	1	51.4	16.4	E	46 41	60 32
FD0019	Dundas #4	1	37.2	33.9	E	46 43	60 32
FD0020	Dundas #3	1	50.6	22.4	E	46 43	60 32
FD0021	White Hill	1	31.2	10.6	E	46 42	60 35
FD0022	Sunday	1	36.2	45.4	E	46 44	60 37
FD0026	Deer	1	12.0	58.3	E	46 46	60 38
FD0030	Indian	1	34.2	29.0	E	46 40	60 34
FD0031	Round	1	33.6	23.9	E	46 48	60 30

Appendix B

NAQUADAT number, name, Cluster group, Area and location of Newfoundland lake sites in the monitoring network. The "C" denotes the cluster group and "Z" the zone in which the lake is found.

Station #	Lake name	C	A	C_b	Z	Lat.	Long.
						° ' "	° ' "
YH0011	unnamed	1	20.4	38.3	F	49 33 00	57 43 15
YH0012	unnamed	1	22.7	45.8	F	49 31 24	57 42 39
YH0013	unnamed	1	6.4	20.8	F	49 35 48	57 44 00
YH0014	unnamed	1	31.3	31.4	F	49 26 14	57 31 54
YH0015	unnamed	1	38.7	36.1	F	49 27 39	57 31 30
YK0006	unnamed	4	22.2	177.1	F	48 47 45	57 39 37
YL0001	unnamed	4	61.3	187.2	F	49 24 28	57 13 18
YL0010	unnamed	1	26.0	26.8	F	49 30 00	57 32 44
YM0001	Noble Pond	1	25.9	65.7	J	49 49 05	55 54 51
YM0003	unnamed	3	59.1	87.2	J	49 32 29	56 38 16
YM0006	unnamed	3	75.1	130.3	J	49 44 29	56 10 01
YM0007	unnamed	5	112.7	103.9	J	49 50 39	56 05 44
YN0008	Sandy	4	74.5	171.7	J	48 49 04	56 56 43
YO0009	Tally Pond	2	23.3	99.7	J	48 36 34	56 29 27
YQ0001	Bellman's Pd	4	50.1	135.8	J	49 10 46	54 39 07
YQ0020	Headwater	4	49.3	204.9	J	48 16 00	55 28 59
YQ0021	Spruce Pond	4	63.5	227.8	J	48 19 00	55 28 00
YR0005	unnamed	3	55.8	50.1	J	49 12 05	54 08 00
YS0003	Rattle Pond	3	57.0	97.2	G	48 30 50	53 49 28
YS0005	Shallow #3	3	61.7	101.9	G	48 30 15	53 49 30
YS0009	Ochre Hill Pd	3	73.4	98.9	G	48 30 10	53 57 50
YS0010	Chatman W.	5	88.9	131.7	G	48 29 39	53 59 03
YS0016	unnamed #2	4	68.1	143.5	G	48 33 00	53 51 00

YS0021	Bog Pond	3	48.4	62.7	G	48 29 39	54 07 59
YS0029	Long Waters	3	57.3	91.1	G	48 27 29	54 03 20
YS0045	Jay Pond	5	108.9	133.6	G	48 38 12	53 53 03
YS0048	Moses Cove	3	52.8	81.7	G	48 35 48	53 45 16
ZB0001	Big Pond	1	22.9	45.3	H	47 50 54	58 13 18
ZB0005	unnamed	1	23.2	50.0	H	47 49 00	58 55 59
ZB0007	unnamed	1	41.7	45.1	H	47 43 00	58 55 00
ZC0002	unnamed	1	22.5	28.9	H	47 48 06	57 18 43
ZC0003	Stephenson's	1	30.9	50.9	H	47 54 45	57 29 47
ZC0016	unnamed	1	18.2	34.0	H	48 00 00	57 45 00
ZC0017	unnamed	1	34.4	40.8	H	47 46 59	57 46 59
ZD0001	unnamed	1	37.2	61.3	H	47 48 39	56 34 54
ZD0002	unnamed	3	83.1	67.6	H	48 04 31	56 41 33
ZF0003	unnamed	1	18.8	49.8	H	47 50 03	54 49 13
ZF0004	Hungry Grove	2	37.1	80.0	H	47 50 42	55 07 00